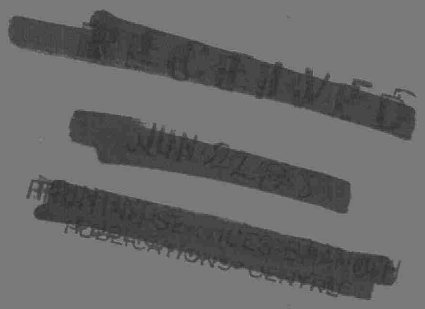
AIR QUALITY ASSESSMENT STUDIES

FOR THE TOWN OF ESPANOLA



Ontario
Ministry of the Environment

AIR QUALITY ASSESSMENT STUDIES FOR THE

TOWN OF ESPANOLA

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AIR QUALITY ASSESSMENT SECTION

NORTHEAST REGION

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I INTRODUCTION

In July 1975, the Ontario Ministry of the Environment established an ambient air quality monitoring program in the town of Espanola in order to determine the quality of the air in the community.

The major industrial activity in the town is the Eddy Forest Products Limited pulp and paper mill located northeast of the town and on the southern shore of the Spanish River (see Figure 1). The mill uses a kraft pulping and bleaching process to produce bleached kraft pulp and finished paper.

The emissions from the kraft process include both gaseous and particulate matter. The gaseous emissions are principally hydrogen sulphide (H_2S), methyl mercaptan (CH_3SH), dimethyl sulphide ($(CH_3)_2$ S), dimethyl disulphide ($(CH_3)_2$ S_2), and sulphur dioxide (SO_2). The particulate emissions are largely sodium sulphate (Na_2SO_4) from the recovery boiler as well as calcium compounds from the lime kiln. Another potential source of particulates is the chip pile adjacent to the mill from which wood chips and fine sawdust could be emitted.

In July 1975, a dustfall monitoring survey was established to determine the levels of particulates around company property and in the community.

Air Quality Assessment staff also conducted vegetation and soil sampling programs in 1976, and snow sampling programs in January 1976 and 1977. Chemical analyses of vegetation, soil and snow samples were performed in order

to determine the concentrations of various elements and compounds in same.

In addition, in February and June 1975, the Mobile Sampling Unit from the Ministry's Air Resources Branch conducted an air sampling survey to determine the ground level concentrations of hydrogen sulphide and sulphur dioxide.

II AIR QUALITY MONITORING PROGRAM

In July 1975, 4 dustfall collectors were installed in the town of Espanola at the following locations (see Figure 1):

SITE NO	LOCATION
1	Spanish River Bridge, Highway 68
2	Corner of Secord and Marguerite Streets
3	Station Road
4	Vicinity of St. George the Martyr Anglican Church.

In addition, a dustfall collector was also installed at McKerrow (Site 5), a small community located approximately 2.5 kilometres northeast of Espanola.

The dustfall collectors are open top plastic containers (approximately 30 cm high and 15 cm diameter), and are usually installed on hydro poles about 4.5 metres above ground in order to minimize the collection of re-entrained particulates from the ground. The containers collect particulate matter generally larger than 10 microns (1 micron = 10^{-6} metres) which settles to the ground by gravitational forces, i.e. by virtue of their weight. The collectors are normally left exposed to the atmosphere for a period of 30 days. The weight

of dust collected during that time period is determined and expressed as a weight of material deposited on a unit surface area during a 30 day period.

The expression used to determine total dustfall is the following:

$$\text{Total Dustfall} = \frac{W \times 30 \text{ days}}{A \times N}$$

where W = weight of dust collected (grams)

A = area of the top of the collecting jar (metres^2)

N = number of days exposed

Total dustfall is expressed in units of grams/metre^2/30 days. In addition, the material collected can be analyzed for various metals and compounds.

In Ontario the criterion for total dustfall is 7.0 grams/metre^2/30 days. For desirable ambient air quality in the Province, the level of dustfall should not exceed this figure. The annual criterion has been set at 4.6 grams/metre^2/30 days.

(a) Dustfall Measurements

1) Total Dustfall

The results of the total dustfall monitoring survey from July 1975 to December 1976 are illustrated in Tables 1 and 2. The sampling site locations are presented in terms of their distance and direction from the main stack of the pulp and paper mill (see Figure 1). Due to technical problems encountered in the operation of the survey, data for August 1975 were not available. The average dustfall levels during both years were determined for each station, as well as the average monthly levels at each location.

From the data it is observed that the monthly criterion was exceeded on 6 occasions in 1975, out of a total of 24 samples. In 1976, the criterion was exceeded on 27 occasions from a total of 58 samples. A breakdown of the number of excessive readings by sampling location is presented in the following table:

SITE NO.	LOCATION*	NUMBER OF TIMES ABOVE MONTHLY CRITERION	
		1975	1976
1	0.45 Km NW	2	11
2	1.40 Km S	1	Nil
3	0.35 Km S	2	10
4	0.60 Km SW	Nil	5
5	2.50 Km NE	1	1

* Distance and direction from main stack

In addition, in 1976 the annual criterion of 4.6 grams/metre^2/30 days was exceeded at Sites 1, 3 and 4 with annual means of 12.9, 13.1 and 5.9 grams/metre^2/30 days respectively. These sampling locations are within 0.6 Km of the main stack. The other sampling sites are further removed from the plant.

From October 3, 1975 to February 21, 1976 the pulp and paper mill was shut down due to an extensive labour strike. This shut down is reflected in lower dustfall levels during this period especially at Sites 1, 3 and 4. At Site 1, there appears to have been significant contributions to total loading from the traffic on the bridge, as evidenced by the elevated dustfall level in January 1976 during the strike period. Conversely, fairly low levels were obtained from October to December 1975 (during the strike), suggesting that at times the mill contributes substantially to the particulate loading measured at that location. This

is further substantiated by the fact that the dustfall levels there were from 3 to 4 times higher during the October to December 1976 period than during the same period in 1975. The second location, i.e. Site 3, where high dustfall levels have also been measured, appears to be more representative of the dust emissions from the mill owing to its proximity to the plant and to the absence of other significant dust sources in the vicinity of the sampling site. The monthly variations in dustfall at that location, shown in Figure 2, indicate very low levels during the strike period, compared to periods when the mill was operative. At this location, the high values obtained when the mill was in full operation and also when snow cover and freezing conditions were absent, could have partly resulted from wood chips and fine sawdust from the wood chip pile located at approximately the same distance from the sampling location as the main stack (see Figure 1).

The average dustfall levels at each location for the period July 1975 to December 1976 (omitting the data during the strike) were analyzed as a function of the distance of the sampling locations from the main stack. The results are illustrated in Figure 3. It is evident that as the distance from the main stack to the sampling location increases, the average dustfall levels decrease rapidly initially and appear to become fairly constant at distances greater than about 1.4 kilometres. This indicates that the pulp and paper mill contributes substantially to the levels of dustfall measured in Espanola and that the material comprising dustfall settles fairly quickly once emitted from the mill.

2) Dustfall Analysis

The dustfall collected at the 4 locations in Espanola and at McKerrow was further analyzed for calcium, sodium and soluble sulphates ($SO_4^{=}$). These substances, as mentioned earlier, are normally emitted as particulates from pulp and paper mills using the kraft process. Since these compounds are all highly soluble, only the soluble fraction of dustfall (i.e. the fraction passing through a Whatman 41 filter paper) was retained for analysis.

i) Calcium Compounds

The analytical data for the calcium analysis are presented in Tables 3 and 4. The values are in grams/metre^2/30 days. The average levels of calcium in dustfall at each location are plotted as a function of distance from the main stack and are shown in Figure 4. The levels of calcium are elevated at Sites 1 and 3 which are located within about 0.5 km of the main stack and these levels do not decrease substantially with increasing distance from the main stack for distances greater than about 0.6 km. Hence the calcium particulate emissions from the mill appear to be limited to the area adjacent to the plant.

ii) Sodium Compounds

The results for the sodium analysis in dustfall are presented in Tables 5 and 6. The lowest values were recorded during the strike period in November and December 1975, whereas maximum levels were obtained in January, March and April 1976. These higher values during the winter months could serve as evidence of sodium contamination from road salt. The sampling site most likely to be affected by road salt contamination is Site 1 (Spanish River Bridge). In 1975 however, the highest sodium values were obtained in July and September with levels in the order of 4 times those in

November and December indicating that the mill is a source of sodium contaminant. But in January 1976, at a time when the paper mill was shut down, a maximum level of 7.6 grams/ metre^2/ 30 days was obtained, clearly indicating road salt contamination.

At Site 3, located 0.35 km S of the main stack, the levels of sodium in dustfall were definitely lower during the strike period as illustrated in Figure 5. This is also the case at Site 4 which is about 0.6 km from the main stack.

The average levels of sodium at each location for the sampling period from July 1975 to December 1976, except the strike period, were also plotted as a function of distance from the main stack as shown in Figure 6. Again, Sites 1 and 3 recorded the highest values. The levels of sodium also decreased gradually with distance from the plant such that the levels were still decreasing with distance as far away as 2.5 km. It should be noted at this time that the average sodium levels in dustfall at each location are over 10 times higher than the corresponding calcium levels.

iii) Soluble Sulphates ($SO_4^{=}$)

The results of the soluble sulphate analyses are presented in Tables 7 and 8. In general, the average levels at each location were higher than the sodium levels by about a factor of 3. Analysis of the data show that the soluble $SO_4^{=}$ levels in dustfall were definitely lower during the strike period.

The average sulphate levels, excluding the data collected during the strike, show a strong gradient as a function of distance from the pulp and paper mill as illustrated in Figure 7. The figure shows a sharp decline in the sulphate levels within a radius of about 0.8 km from the main stack. Thereafter the decline in the levels is more gradual. For comparison, in 1975 the maximum soluble sulphate levels in dustfall in the city of Sudbury were in the order of 1.0 gram/metre^2/ 30 days, whereas the average levels at locations outside the city, but within the Sudbury basin varied from 0.3 to 0.7 grams/metre^2/30 days. Hence the sulphate levels at McKerrow (Site 5) are comparable to the background levels measured at other locations in the Sudbury basin, whereas the levels in Espanola were considerably higher.

b) Mobile Monitoring Survey

From February 6 to February 8, 1975 and from June 10 to June 14, 1975, the Mobile Sampling Unit from the Technology Development and Appraisal Section, Air Resources Branch, surveyed the air quality in the area surrounding the Eddy Forest Products Ltd. pulp and paper mill in Espanola.

The mobile monitoring unit sampled the air for hydrogen sulphide using a Hartmann and Braun electrochemical analyzer. The half hour ambient air quality standard of 20 parts per billion (ppb) for hydrogen sulphide was exceeded during 10 of the 23 half hour intervals sampled. The values ranged from 7.5 to 67 ppb with an average value of 20.3 ppb. It is appropriate at this point to mention that an odor threshold value of 4.7 ppb has been reported for this compound. During the survey, unfavourable wind directions, did not

permit monitoring at the point of impingement of the plume because of local terrain configuration and inadequate road access. Only on a few occasions was the mobile monitoring unit able to monitor the edge of the plume. Hence it is felt that the maximum values reported above for H_2S could have been higher.

The mobile monitoring unit also sampled the ambient air for sulphur dioxide with a conductivity analyzer (Westhoff-Bochum). The maximum half hourly SO_2 concentration measured was 0.09 ppm, while the mean of the 23 half hours monitored was 0.04 ppm. The provincial ambient air quality standard for this pollutant is 0.30 ppm for a half hour whilst the 1 hour criterion for desirable air quality is 0.25 ppm.

c) Future Work

The ambient air quality monitoring program initiated in Espanola in July 1975 has been expanded in 1977 with the addition of 2 dustfall jars and a high volume air sampler in the town, within a radius of 0.5 km from the main stack of the mill. The high volume air sampler collects the suspended particulates i.e. the particulate matter that remains airborne due to its small size and is not normally collected by dustfall jars. The filters from this sampler are being analyzed for total mass loading and also for calcium, sodium, sulphates and chlorides.

In addition, the contents of the dustfall collectors will be analyzed for total chlorides in order to separate the road salt contributions to the levels of sodium in dustfall from the sodium compound emissions from the mill.

III VEGETATION SAMPLING PROGRAM

(a) Sample Collection

A program to sample vegetation in the vicinity of the paper mill was initiated in 1976. Sampling stations were selected along west and south radii from the mill. The stations (Figure 8) were located in relation to the main stack as follows:

SITE NUMBER	LOCATION
1	100 m W
2	400 m W
3	800 m W
4	50 m SSW
5	440 m S
6	1000 m S
7	200 m N
8	640 m N
9	1200 m N

Triplicate samples of Manitoba maple (Acer negundo L.) foliage were collected at each station (except Site 8) on September 8, 1976. The samples were dried and ground prior to chemical analysis for calcium, magnesium, sodium, sulphur, fluoride and chloride content.

(b) Chemical Analysis Results

The chemical analysis results for the Manitoba maple foliage samples are presented in Table 9. Normal concentrations of calcium, magnesium and fluoride were found in the foliage. With the exception of lower concentrations of magnesium in samples collected on the north radius, no patterns or gradients in concentration of these elements were observed.

Strong gradients for sodium and sulphur concentrations in the foliage were found, with the highest concentration being recorded nearest to the paper mill and decreasing with distance along all three radii (Figure 9). Decreasing chloride concentrations were measured with distance from the mill along the south and west radii, however on the north radius, at Site 7 the chloride concentrations were low and no gradient away from the mill could be demonstrated.

(c) Visible Particulate on Foliage

During the period of sample collection for the vegetation sampling program, a white particulate material was observed on foliage of various plants. The heaviest deposits were found nearest to the paper mill and decreased in amount with increasing distance from the mill. A map was prepared to show the extent of the area affected (Figure 10). The presence of the particulate was more evident to the south and west of the mill. This pattern does not coincide with the pattern of sodium contamination of vegetation described above where Site 7 (200 m N) was among the most highly contaminated sites. This can be explained on the basis that rain periodically washes the visible particulate from the foliage. Prior to the observation date, particulate emissions occurred only during periods of north and easterly winds. The sodium contamination at Site 7 as determined by chemical analysis would have been the cumulative effect of sodium over the entire growing season.

IV SOIL SAMPLING PROGRAM

(a) Sample Collection

A program of soil sampling in the vicinity of the paper mill

was initiated in 1976. This program was carried out in conjunction with the vegetation sampling program. Soil samples were also collected at the same sites as the vegetation samples. Triplicate soil samples (0-10 cm) were collected at each of the 9 sites (Figure 8). The samples were dried, ground and analysed for sodium, calcium, magnesium, fluoride, chloride and sulphur content.

(b) Chemical Analysis Results

The chemical analysis results of the soil samples are presented in Table 10. The concentrations of all elements are within the normal concentration ranges to be expected for the respective elements and no pattern of contamination could be demonstrated.

V SNOW SAMPLING PROGRAM

(a) Sample Collection

A program of snow sampling in the vicinity of the paper mill was initiated in 1976 during the period when the mill was not operating due to a labour strike. In January 1976, a total of 12 sites were selected. In January, 1977, 5 more sites were selected. Samples were collected from these sites as indicated in the following table:

SITE NUMBER	LOCATION	SNOW SAMPLES COLLECTED IN:	
		1975	1976
1	110 m W	-	x
2	220 m NW	-	x
3	440 m SE	-	x
4	550 m S	x	x
5	1000 m S	x	x
6	1750 m S	x	x
7	660 m W	x	x
8	1000 m W	x	x
9	1500 m W	x	x
10	2000 m W	x	x
11	440 m N	x	x
12	825 m N	x	x
13	1250 m N	x	x
14	1000 m NE	x	x
15	10 km NE	-	x
16	14 km NE	-	x
17	2.5 km NE	x	-

On January 30, 1976 and January 11, 1977, duplicate snow samples were collected at each of the sites indicated above, (Figure 11). The samples consisted of circular cores of snow, 7.5 cm in diameter and represented a complete profile of the snow from the surface to the ground level. The sample was taken in such a manner as to avoid contamination by ground materials. The number of cores required to fill 4.5 kg polyethylene bags was recorded. The samples were returned to the laboratory and allowed to melt overnight at room temperature in the polyethylene bags. The volume of snow melt-water was measured and a pH measurement taken immediately. Each sample was then analysed for SO_4, Na, Cl, Ca, Mg, K and alkalinity. In addition conductivity, iron and tannin and lignin concentrations were determined for the 1977 collections.

At the time of the sampling the total depth of snow was recorded as well as depth of fresh snow and the number of crust layers. Notes were made on the number and the type of

any banding or layering in the snow profile. The presence of black precipitate in the melt-water was noted and rated on an arbitrary scale of none to heavy.

(b) Results of Chemical Analysis

The condition and depth observations made on the snow samples collected in 1976 and 1977 are presented in Tables 11 and 12 respectively. Snow depths ranged from 33 to 54 cm in 1976 and from 34 to 68 cm in 1977. No visible contamination of snow was observed in 1976 (strike year) while up to seven orange-brown bands were observed in the snow profile in 1977. The number and intensity of these bands decreased with increasing distance from the paper mill. Microscopic examination of the material responsible for the coloured bands revealed that the material was very fine wood particles. This observation is further substantiated by the tannin and lignin analyses (Table 14).

The mean concentrations of the various chemical elements and other parameters measured in the snow samples are presented in Tables 13 and 14. Results of samples collected in 1976 (strike year) indicated that the snow was essentially clean and uniform. This is in contrast with the 1977 results which showed strong contamination by SO_4 and Na, and to a lesser degree by Cl, Ca and K. Very limited increases in Mg levels were measured between the 1976 and 1977 collections. As might be expected from the chemical concentration changes indicated above, the alkalinity and subsequently the pH also increased in the 1977 samples.

The analysis results (1977) for the SO_4, Na, Cl, Ca, Mg, K, Fe, tannin and lignin concentrations, as well as alkalinity, pH and conductivity all showed that the highest values were found in close proximity to the paper mill and decreased with distance from the mill (Figure 12). The highest values for nearly all of these parameters were recorded at Site 2 (220 m NW). Sites 5, 13 and 15 (Control) could be subjected to light road salt contamination as indicated by the Na and Cl concentrations in the samples collected at these sites. The pH value of the snow collected at Site 15 could have been elevated due to this contamination. A control snow sample collected 150 km west of Espanola had a pH value of 5.0 which is probably a more realistic value for a control snow sample.

VI SUMMARY

The dustfall monitoring survey indicates that total dustfall, and the levels of calcium, sodium and soluble sulphates in dustfall, on average, are elevated and decrease with increasing distance from the mill. Further, the levels of dustfall and of the above substances in dustfall were observed to have decreased markedly during a labor strike period from October 1975 to February 1976 when the mill was shut down completely. This was particularly evident for total dustfall and for the soluble sulphates in dustfall. This indicates that the kraft pulp and paper mill at Espanola is the major source of these airborne particulate contaminants in the community and hence has a significant impact on the local air quality.

Ground level concentrations of H_2S, as measured by the mobile monitoring unit, were found to exceed the provincial

half hour air quality standard and criterion on a considerable number of occasions during two brief air monitoring surveys at Espanola. The measured levels of SO_2 were found to be well within the half hour standard value.

Samples of soil and Manitoba maple foliage were collected in the vicinity of the paper mill in September, 1976. Elevated levels of sodium and sulphur were found in the vegetation in close proximity to the mill, with decreasing concentrations of these elements in the foliage with increasing distance from the mill. No pattern of soil contamination with respect to the mill location could be determined for any of the elements investigated. A zone of white particulate contamination of plant foliage surfaces was delineated to the south and west of the paper mill.

Snow samples collected in the Espanola area in January 1976 (a strike year) indicated that the snow was essentially clean. This is in strong contrast with the 1977 results (an operational year) which showed strong contamination by SO_4 and Na, and to a lesser degree by Cl, Ca and K. The analysis results of the 1977 samples indicated that the highest concentrations of SO_4, Na, Cl, Ca, Mg, K, Fe and tannins and lignins, were recorded in close proximity to the paper mill and decreased with distance from the mill. Alkalinity pH and conductivity values were also highest at these same sites.

VII ACKNOWLEDGEMENTS

The authors wish to express their thanks to: Mr. W. J. Gibson, Manager, Technical Support Section and Dr. D. Balsillie, Chief, Air Quality Assessment for supervision, advice and support; Dr. S. N. Linzon and staff of the Phytotoxicology Section, Air Resources Branch for technical advice and handling of the vegetation and soil samples; Mr. A. C. Rayner and the staff of the Air Quality Laboratory for chemical analysis of the vegetation and soil samples (Mr. R. Wills), and for analysis of dustfall jars (Mr. M. Metzger and Dr. B. Foster), Mr. K. Waldie for maintenance of air quality sampling equipment; Dr. E. Singer for providing air quality monitoring data; Ms. S. Legault for secretarial assistance. As a result of the co-ordinated effort of all these people, the presentation of this report was made possible.

VIII APPENDIX

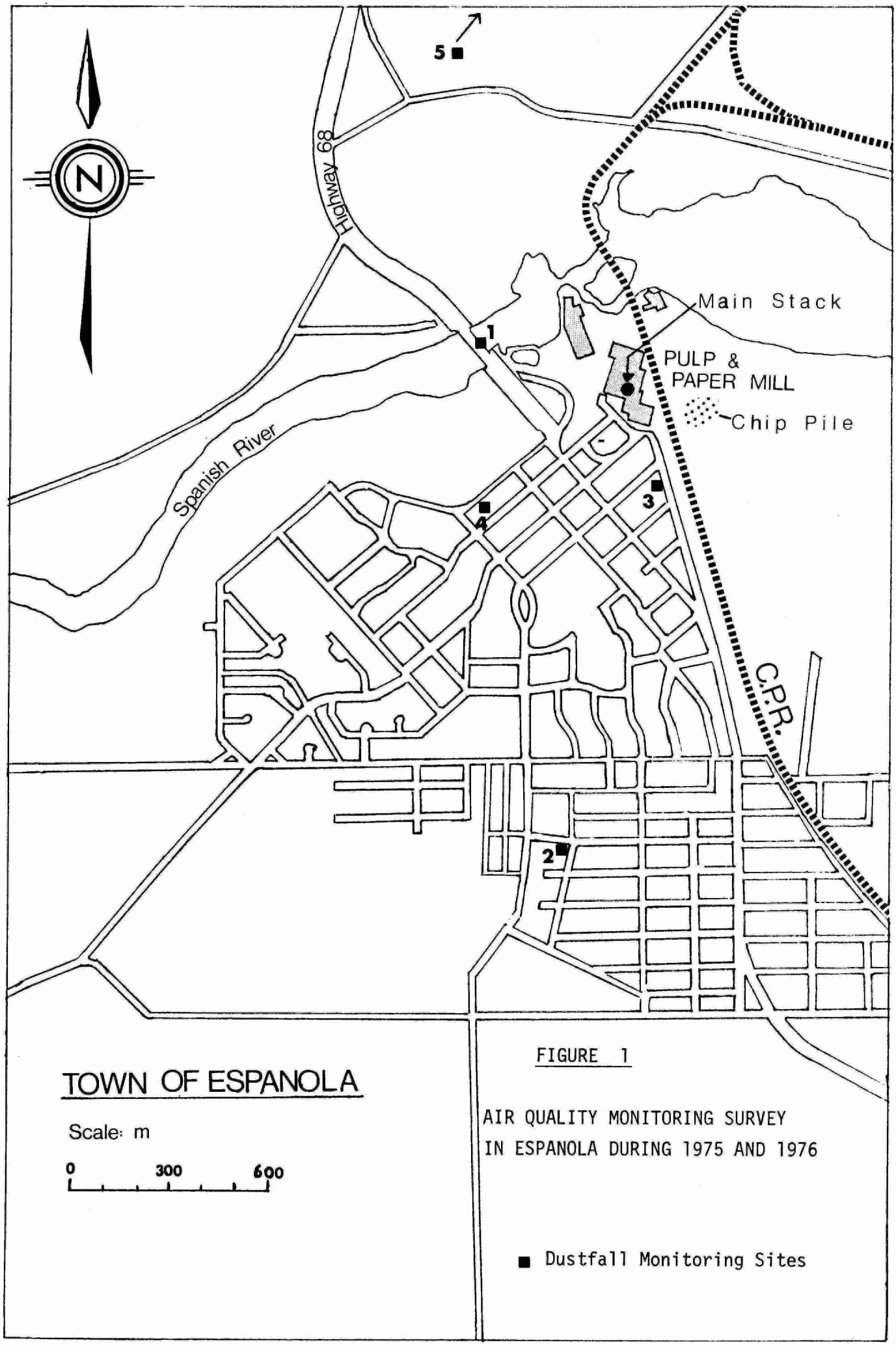

N
5
Highway 68
Main Stack
1
PULP &
PAPER MILL
Chip Pile
Spanish River
4
3
C.P.R.
2
TOWN OF ESPANOLA
Scale: m
0
300
600
FIGURE 1
AIR QUALITY MONITORING SURVEY
IN ESPANOLA DURING 1975 AND 1976
Dustfall Monitoring Sites

FIGURE 2 AVERAGE MONTHLY DUSTFALL LEVELS IN ESPANOLA AT SITE 3 FROM JULY 1975 to DECEMBER 1976

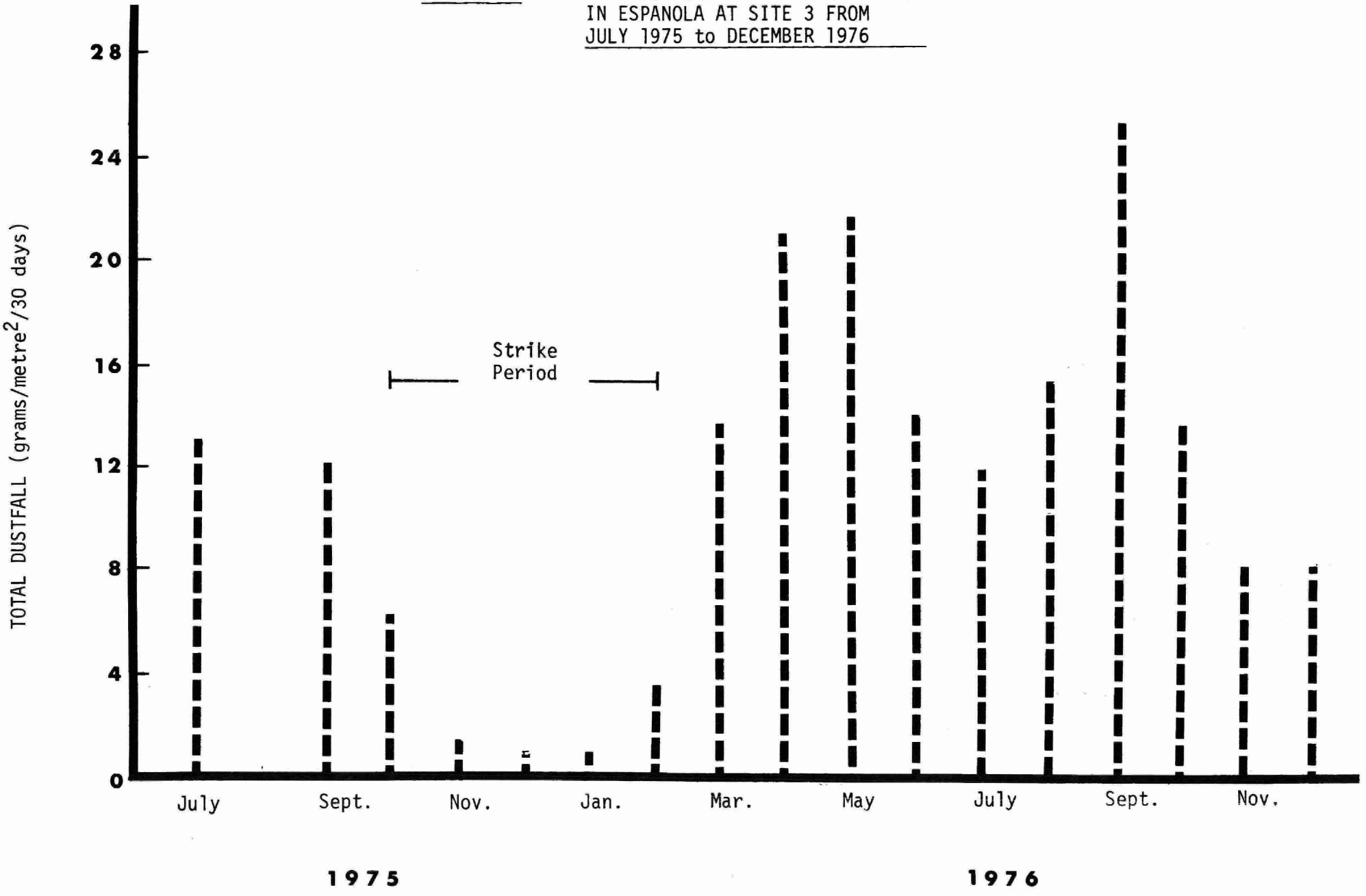


FIGURE 3

AVERAGE DUSTFALL LEVELS IN ESPANOLA DURING 1975 AND 1976 AS A FUNCTION OF SAMPLING SITE DISTANCE FROM MAIN STACK

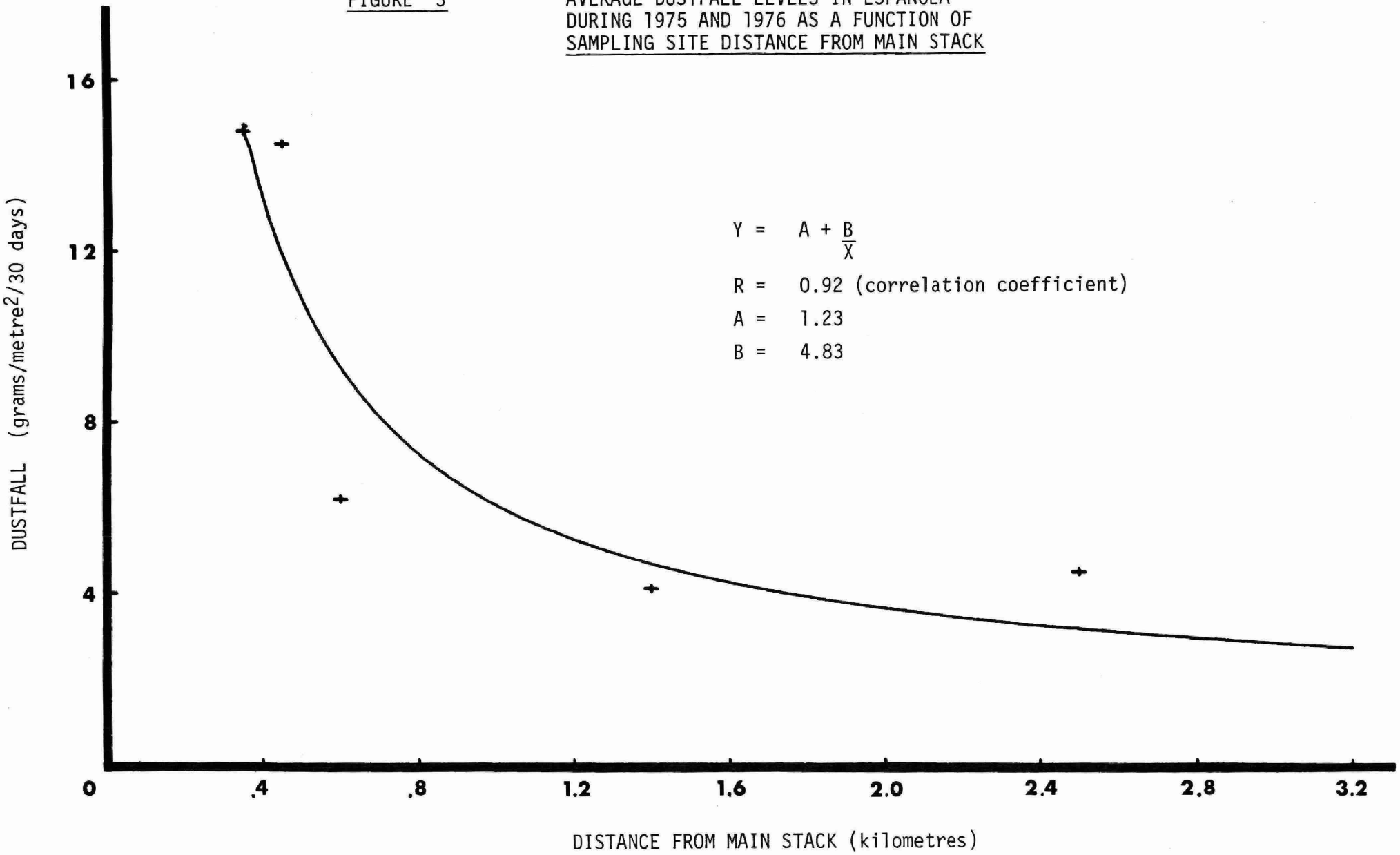


FIGURE 4

AVERAGE CALCIUM LEVELS IN DUSTFALL IN ESPANOLA DURING 1975 AND 1976 AS A FUNCTION OF SAMPLING SITE DISTANCE FROM MAIN STACK

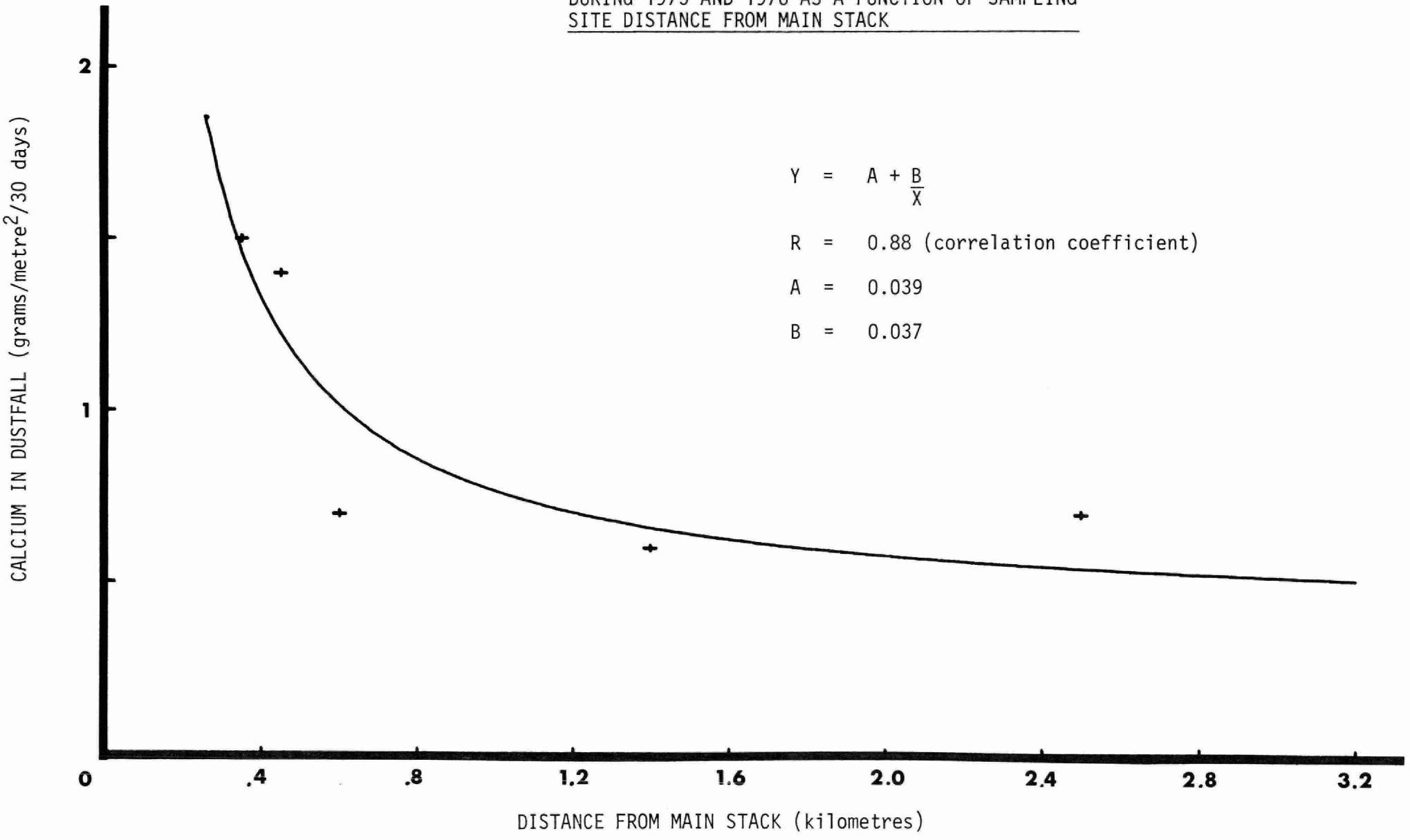


FIGURE 5

AVERAGE MONTHLY SODIUM LEVELS IN DUSTFALL AT SITE NO. 3 IN ESPANOLA FROM JULY 1975 TO DECEMBER 1976

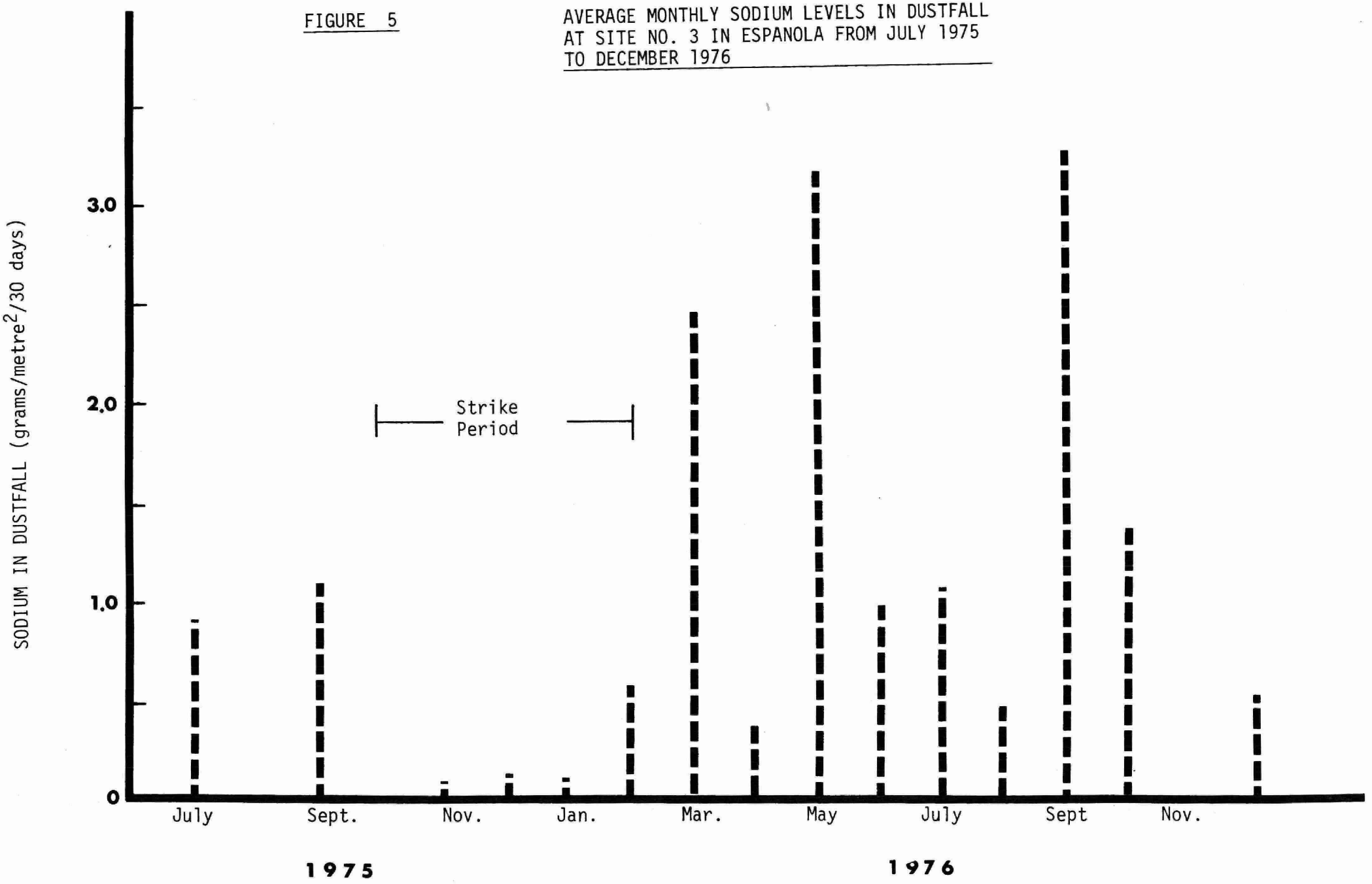


FIGURE 6

AVERAGE SODIUM LEVELS IN DUSTFALL IN ESPANOLA DURING 1975 AND 1976 AS A FUNCTION OF SAMPLING SITE DISTANCE FROM MAIN STACK

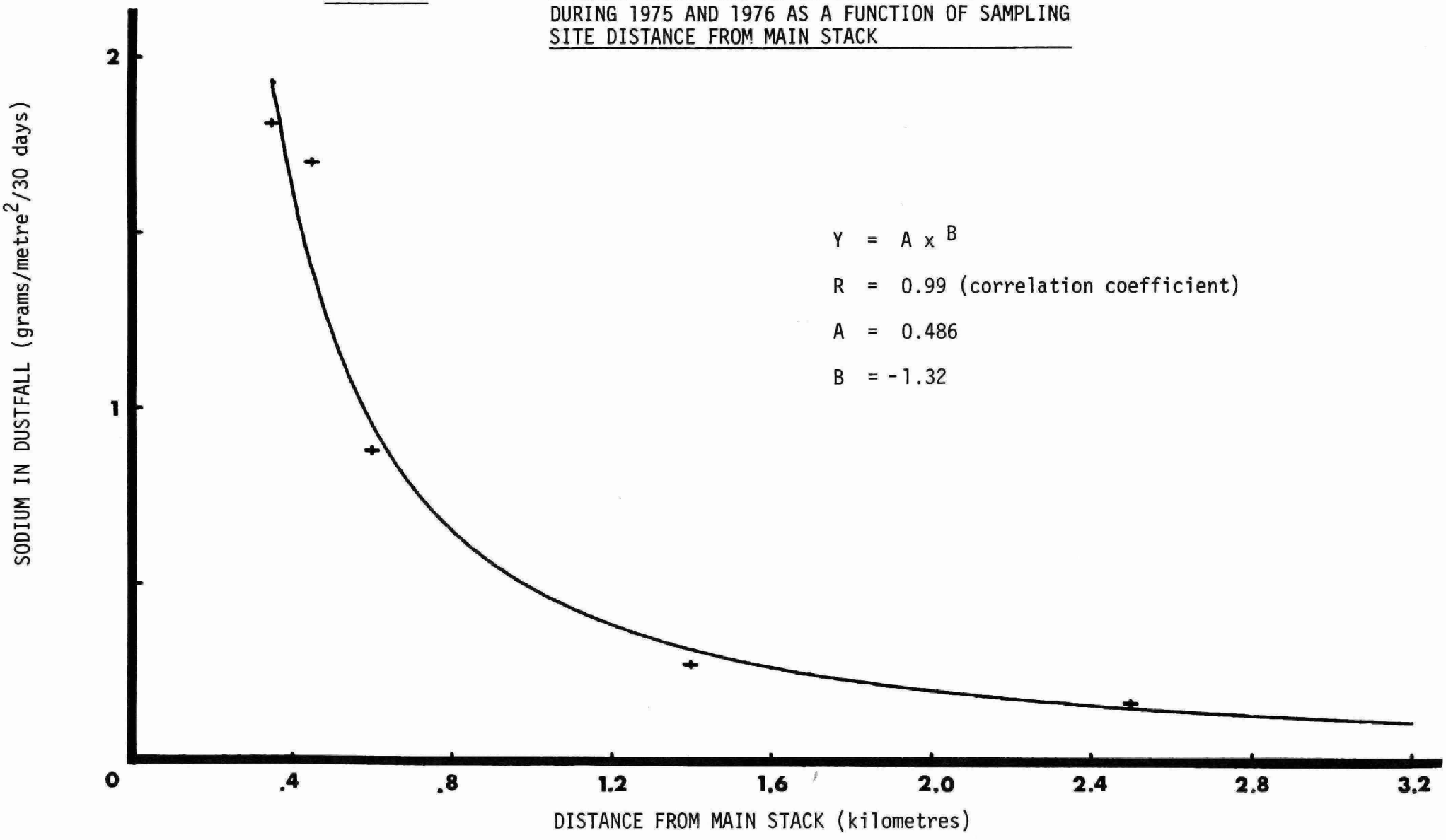
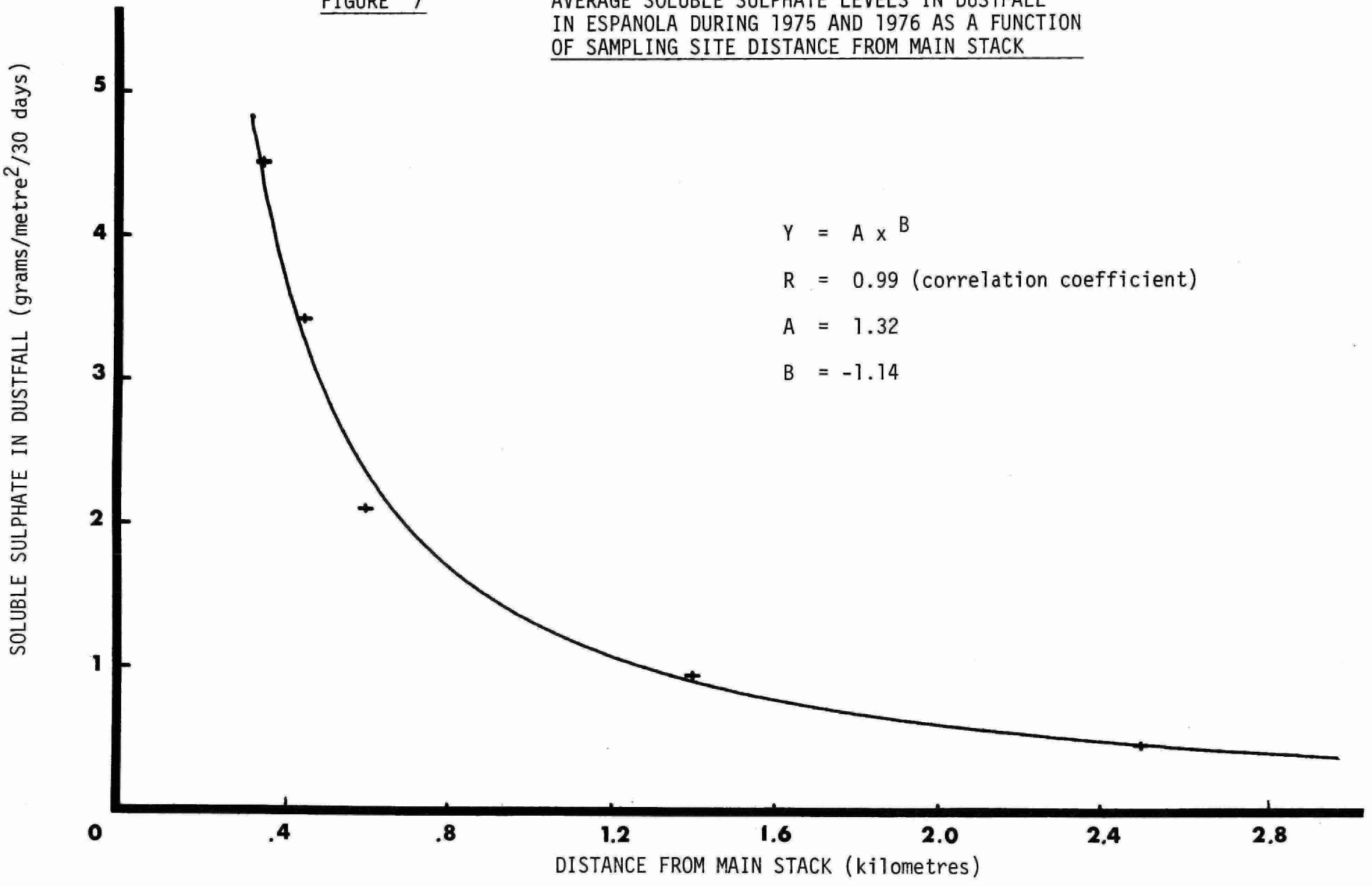
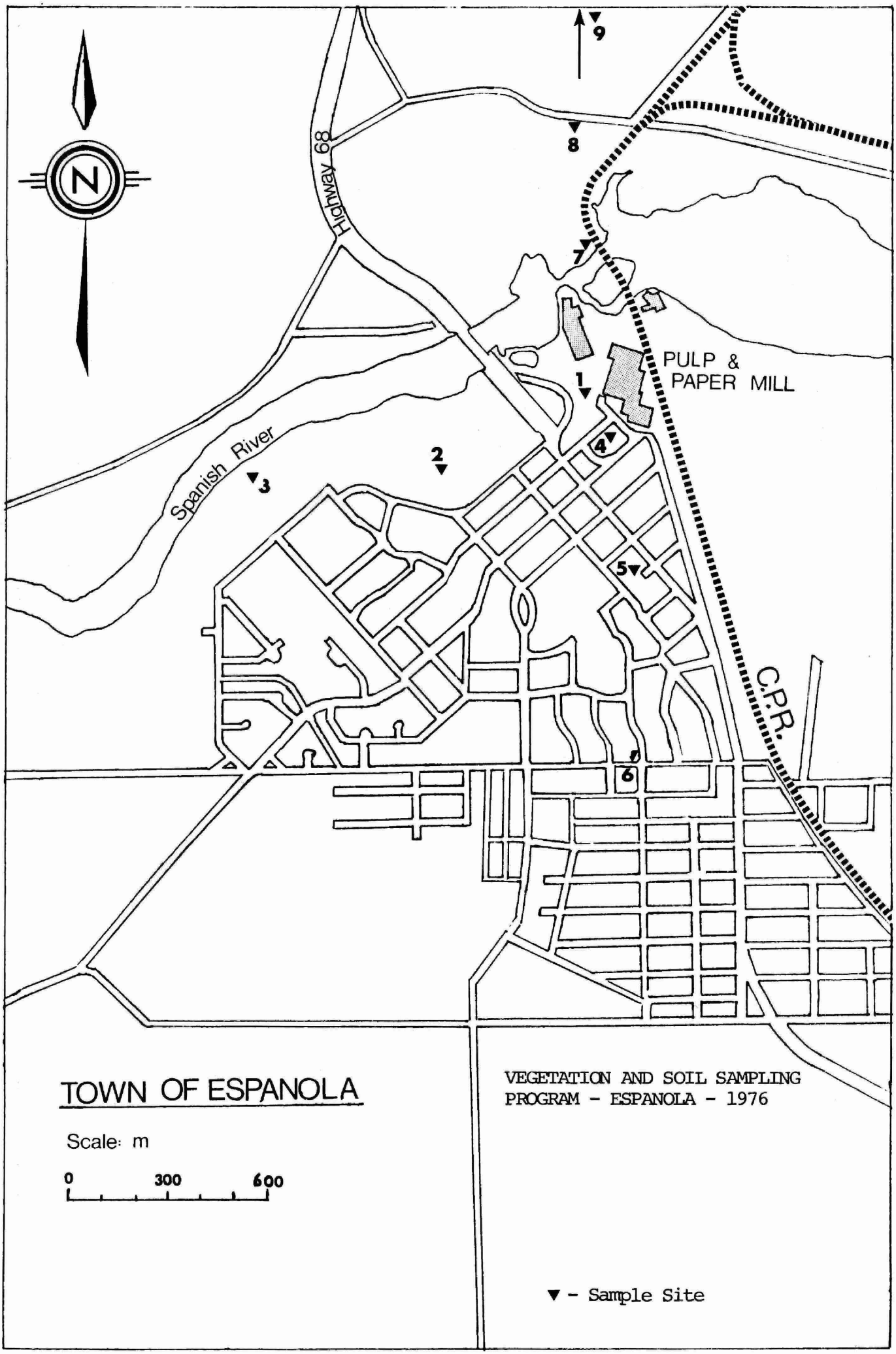


FIGURE 7

AVERAGE SOLUBLE SULPHATE LEVELS IN DUSTFALL IN ESPANOLA DURING 1975 AND 1976 AS A FUNCTION OF SAMPLING SITE DISTANCE FROM MAIN STACK

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Spanish River
PULP &
PAPER MILL
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TOWN OF ESPANOLA
Scale: m
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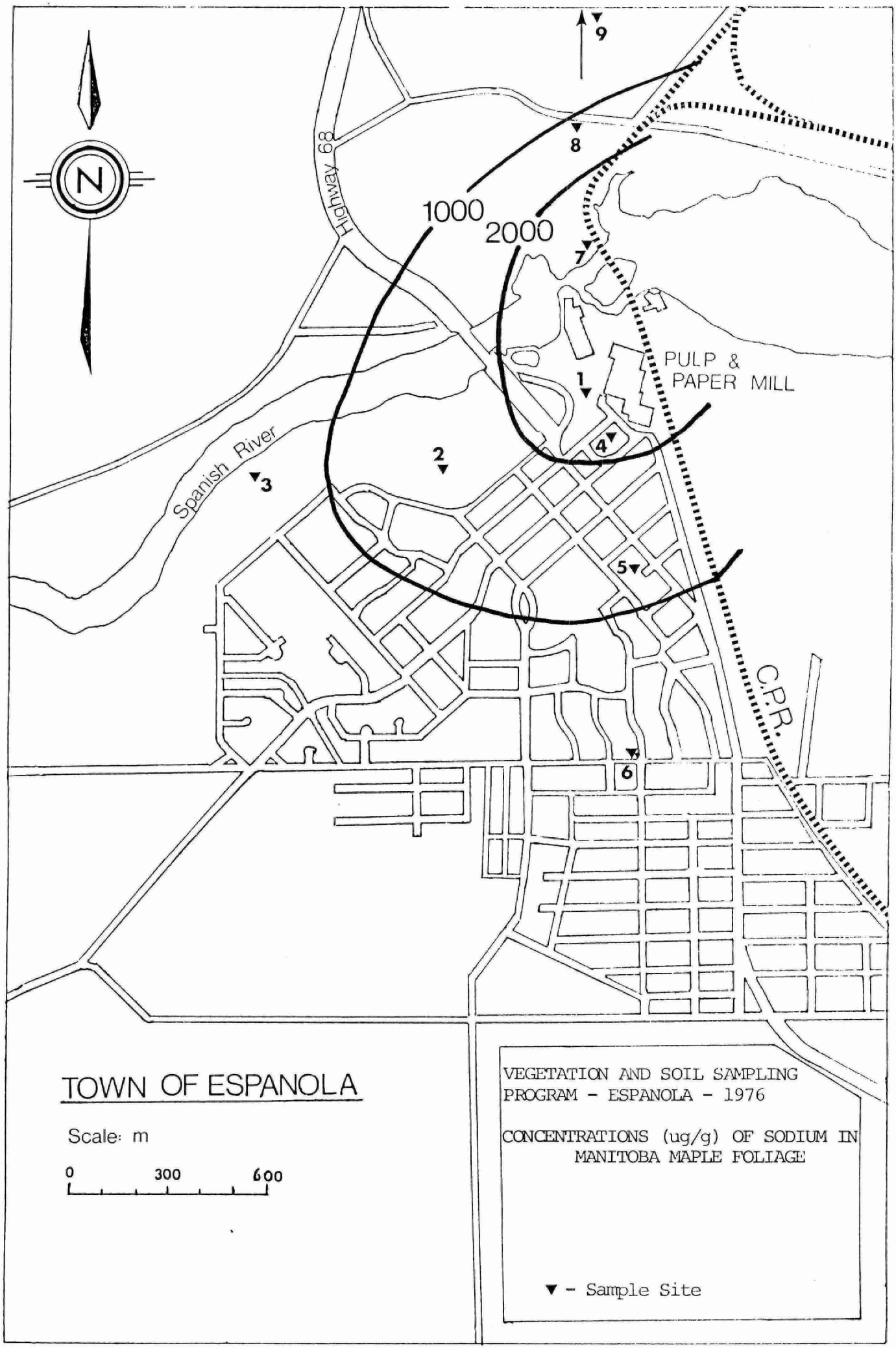
VEGETATION AND SOIL SAMPLING
PROGRAM - ESPANOLA - 1976
▼ - Sample Site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TOWN OF ESPANOLA
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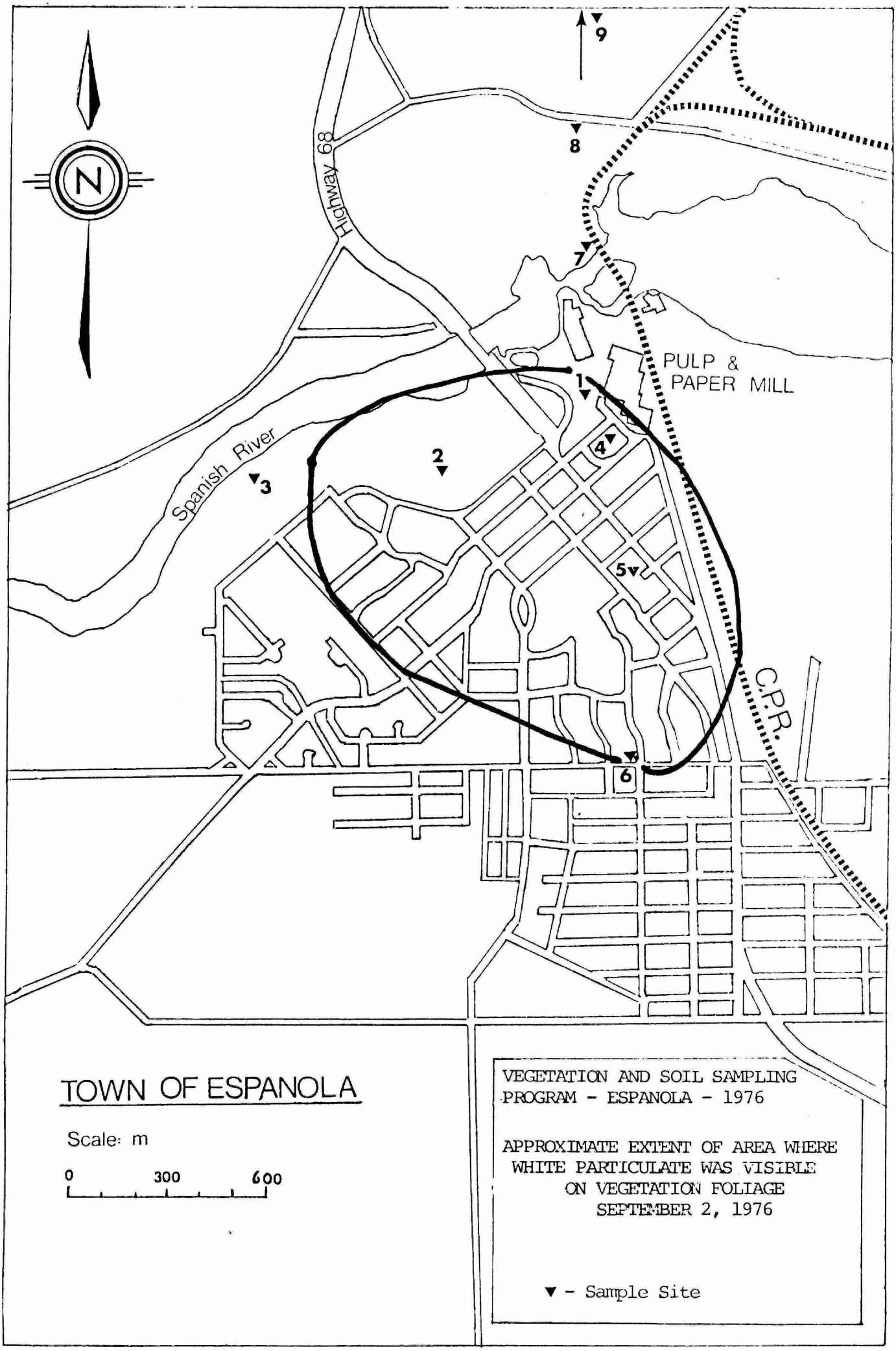
VEGETATION AND SOIL SAMPLING
PROGRAM - ESPANOLA - 1976
CONCENTRATIONS (ug/g) OF SODIUM IN
MANITOBA MAPLE FOLIAGE
▼ - Sample Site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TOWN OF ESPANOLA
Scale: m
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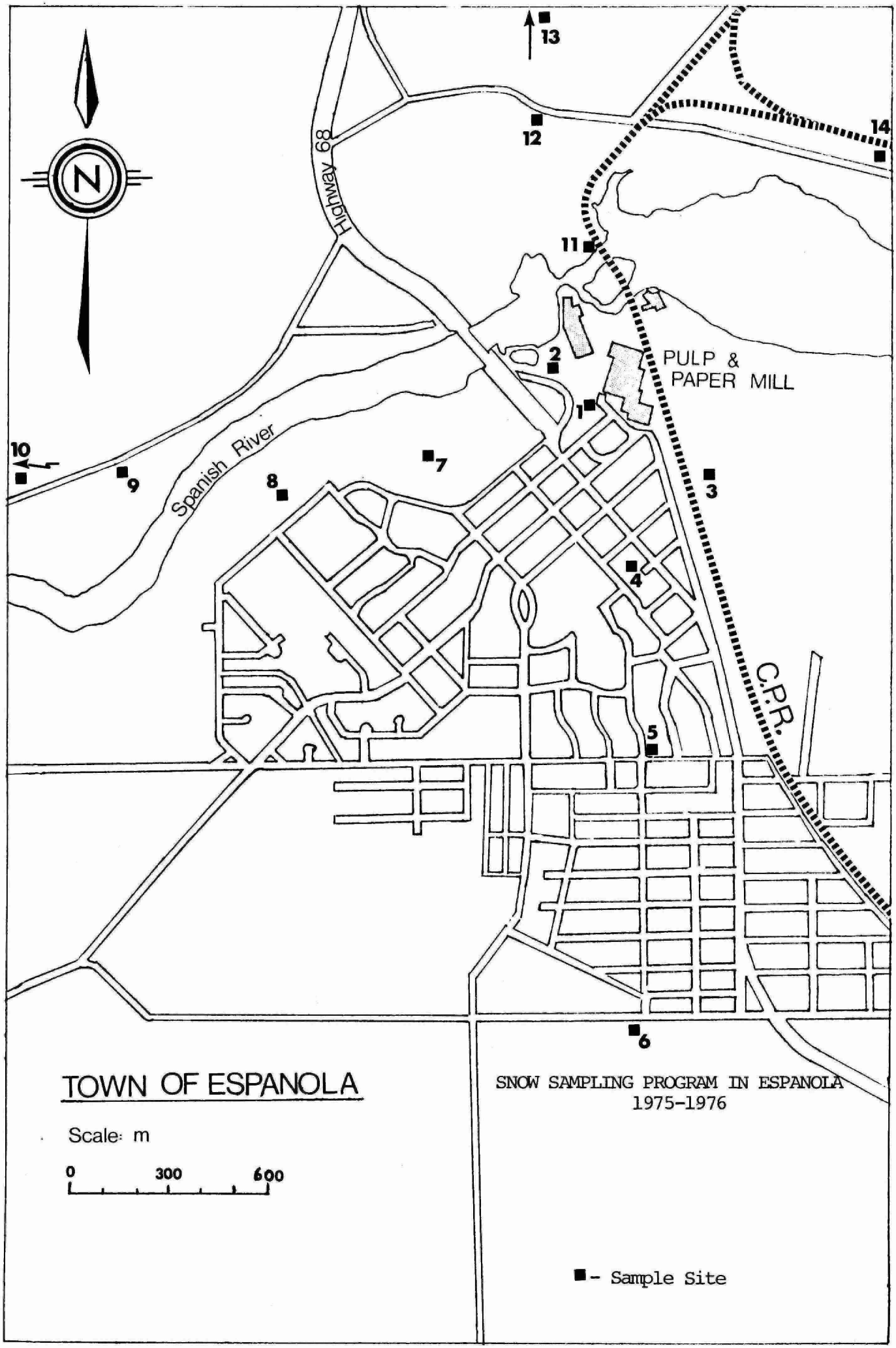
VEGETATION AND SOIL SAMPLING
PROGRAM - ESPANOLA - 1976
APPROXIMATE EXTENT OF AREA WHERE
WHITE PARTICULATE WAS VISIBLE
ON VEGETATION FOLIAGE
SEPTEMBER 2, 1976
▼ - Sample Site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Spanish River
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PAPER MILL
C.P.R.
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14
TOWN OF ESPANOLA
Scale: m
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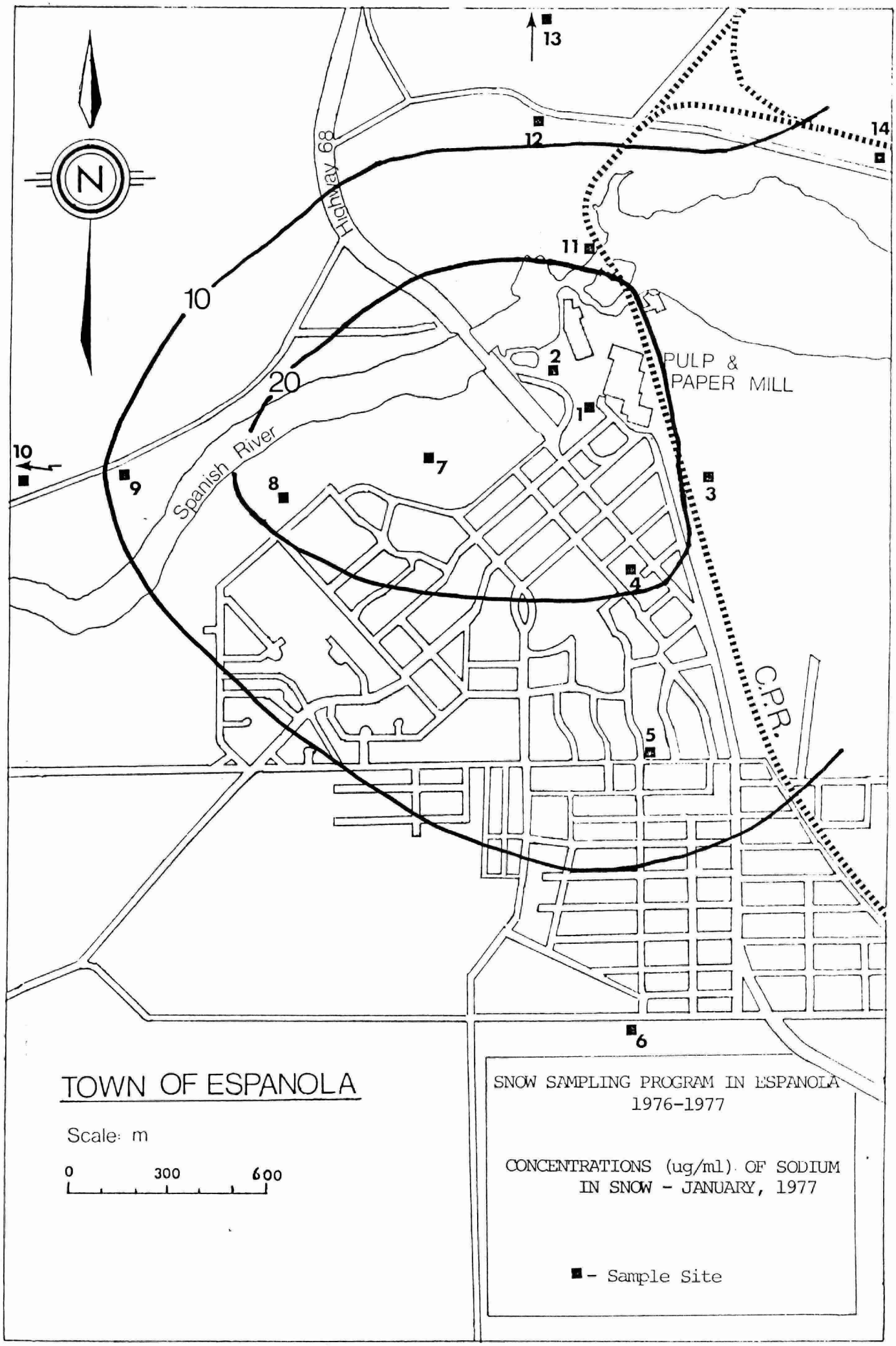
600
SNOW SAMPLING PROGRAM IN ESPANOLA
1975-1976
■- Sample Site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Highway 68
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2
PULP &
PAPER MILL
1
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Spanish River
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C.P.R.
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TOWN OF ESPANOLA
Scale: m
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300
600
SNOW SAMPLING PROGRAM IN ESPANOLA
1976-1977
CONCENTRATIONS (ug/ml) OF SODIUM
IN SNOW - JANUARY, 1977
■ - Sample Site

TABLE 1

TOTAL DUSTFALL LEVELS IN ESPANOLA

DURING 1975 (ALL VALUES IN GRAMS/METRE^2/30 DAYS)

SITE NO.	LOCATION*	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	MEAN
1	0.45 km NW	21.7	-	31.6	3.2	2.4	2.1	12.2
2	1.4 km S	5.3	-	3.2	8.1	1.4	1.0	3.8
3	0.35 km S	13.0	-	12.3	6.3	1.4	1.0	6.8
4	0.60 km SW	6.3	-	2.4	2.1	2.8	1.4	3.0
5	2.5 km NE	10.2	-	-	2.4	1.4	1.0	3.7
	Mean	11.3	-	12.4	4.4	1.9	1.3	

* Distance and direction from main stack.

TABLE 2

TOTAL DUSTFALL LEVELS IN ESPANOLA

DURING 1976 (ALL VALUES IN GRAMS/METRE^2/30 DAYS)

SITE NO	LOCATION*	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MEAN
1	0.45 km NW	20.3	-	28.4	9.5	14.0	12.3	7.7	7.4	14.0	9.8	9.1	9.1	12.9
2	1.4 km S	0.3	1.4	4.2	4.9	5.3	-	2.8	6.0	5.3	5.3	1.4	1.4	3.5
3	0.35 km S	0.7	3.9	13.7	21.0	21.7	14.0	11.9	15.4	25.3	13.7	8.1	8.1	13.1
4	0.60 km SW	0.7	4.2	6.3	6.0	8.1	8.4	5.3	7.4	10.2	8.1	2.4	3.8	5.9
5	2.5 km NE	1.0	2.4	13.0	3.1	2.8	5.3	4.9	5.3	1.0	2.4	1.0	1.0	3.6
	MEAN	4.6	2.9	13.1	8.9	10.4	10.0	6.5	8.3	11.2	7.9	4.4	4.7	

* Distance and direction from main stack.

TABLE 3

CALCIUM IN DUSTFALL COLLECTED IN ESPANOLA DURING 1975

(ALL VALUES IN GRAMS/METRE^2/30 DAYS)

SITE NO.	LOCATION*	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	MEAN
1	0.45 km NW	0.28	-	0.19	0.06	.07	0.04	0.13
2	1.4 km S	0.07	-	0.05	0.12	.07	0.02	0.07
3	0.35 km S	0.18	-	0.07	0.11	0.05	0.02	0.09
4	0.60 km SW	0.08	-	0.04	0.04	0.08	0.02	0.05
5	2.4 km NE	0.09	-	-	0.13	0.08	0.02	0.08
	MEAN	0.14	-	0.09	0.09	0.07	0.02	

* Distance and direction from main stack.

TABLE 4

CALCIUM IN DUSTFALL COLLECTED IN ESPANOLA DURING 1976

(ALL VALUES IN GRAMS/METRE^2/30 DAYS)

SITE NO	LOCATION*	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MEAN
1	0.45 km NW	0.07	-	0.5	0.07	0.07	0.05	0.07	0.08	0.1	0.01	-	0.07	0.11
2	1.4 km S	ND**	0.03	0.1	0.06	0.05	-	0.05	0.05	0.1	0.05	-	0.03	0.06
3	0.35 km S	ND	0.08	0.2	0.2	0.2	0.1	0.2	0.1	0.2	0.2	-	0.06	0.15
4	0.60 km SW	ND	0.07	0.2	0.06	0.04	0.06	0.06	0.04	0.1	0.05	-	0.03	0.08
5	2.5 km NE	ND	0.04	0.4	0.05	0.03	0.07	0.02	0.05	ND	0.02	-	0.02	0.07
	MEAN	0.01	0.06	0.27	0.09	0.07	0.08	0.07	0.07	0.11	0.08	-	0.04	

* Distance and direction from main stack

** Not detectable

TABLE 5

SODIUM IN DUSTFALL

COLLECTED IN ESPANOLA DURING 1975

(ALL VALUES IN GRAMS/METRE^2/30 DAYS)

SITE NO.	LOCATION*	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	MEAN
1	0.45 km NW	1.7	-	1.8	-	0.3	0.4	1.1
2	1.4 km S	0.1	-	0.05	-	0.06	0.02	0.3
3	0.35 km S	0.9	-	1.1	-	0.06	0.03	0.5
4	0.60 km SW	0.4	-	0.2	-	0.07	0.03	0.2
5	2.5 km NE	0.1	-	-	-	0.1	0.08	0.1
	Mean	0.6	-	0.8	-	0.1	0.1	

* Distance and direction from main stack

TABLE 6

SODIUM IN DUSTFALL COLLECTED IN ESPANOLA

DURING 1976 (ALL VALUES IN GRAMS/METRE^2/30 DAYS)

SITE NO.	LOCATION*	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MEAN
1	0.45 km NW	7.6	-	6.8	1.7	1.8	0.7	0.3	0.03	1.5	1.4	-	1.0	2.3
2	1.4 km S	0.03	0.1	0.5	0.4	0.4	-	0.2	0.5	0.2	0.2	-	0.08	0.3
3	0.35 km S	0.07	0.6	2.5	0.4	3.2	1.0	1.1	0.5	3.3	1.3	-	0.6	1.6
4	0.60 km SW	0.04	0.9	1.1	1.3	1.1	1.1	1.1	0.6	1.8	1.1	-	0.2	0.9
5	2.5 km NE	0.2	0.4	0.3	0.4	0.02	0.02	0.03	0.1	0.4	0.09	-	0.1	0.2
	Mean	1.6	0.5	2.2	1.5	1.3	0.7	0.4	0.3	1.4	0.8	-	0.4	

* Distance and direction from main stack

TABLE 7

SOLUBLE SULPHATE ($SO_4^{=}$) IN DUSTFALL

COLLECTED IN ESPANOLA DURING 1975

(ALL VALUES IN GRAMS/METRE^2/30 DAYS)

SITE NO.	LOCATION*	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	MEAN
1	0.45 km NW	3.5	-	6.0	0.4	0.4	0.2	2.1
2	1.4 km S	0.5	-	1.1	1.3	0.3	0.2	0.7
3	0.35 km S	2.1	-	4.3	0.6	0.4	0.1	1.5
4	0.60 km SW	1.3	-	0.8	0.3	0.4	0.2	0.6
5	2.5 km NE	0.4	-	-	0.4	0.4	0.2	0.3
	Mean	1.6	-	3.0	0.6	0.4	0.2	

* Distance and direction from main stack

TABLE 8

SOLUBLE SULPHATE ($SO_4^{=}$) IN DUSTFALL

COLLECTED IN ESPANOLA DURING 1976

(ALL VALUES IN GRAMS/METRE^2/30 DAYS)

SITE NO.	LOCATION*	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	MEAN
1	0.45 km NW	1.6	-	6.5	2.2	5.3	2.2	0.7	1.1	4.2	2.5	1.7	5.1	3.0
2	1.4 km S	0.1	0.4	1.3	1.0	1.4	-	0.5	1.1	1.4	0.9	0.3	0.8	0.8
3	0.35 km S	0.1	1.0	5.1	6.5	8.2	2.5	2.4	2.3	10.1	3.0	4.9	2.7	4.1
4	0.60 km SW	0.1	1.7	2.6	1.7	4.4	2.6	1.2	1.3	3.6	3.2	0.8	1.6	2.1
5	2.5 km NE	0.1	0.3	0.9	0.6	0.6	0.8	0.4	0.6	0.1	0.3	0.2	0.2	0.4
	Mean	0.4	0.8	3.3	2.4	4.0	2.0	5.2	1.3	3.9	2.0	1.6	2.1	

* Distance and direction from main stack

TABLE 9: Concentrations of various chemical elements in Manitoba maple foliage collected in the vicinity of the E.B. Eddy Forest Products Paper Mill at Espanola - September, 1976.

		ELEMENT**					
		Na	Ca	Mg	F	Cl	S
SAMPLE	LOCATION*	(µg/g)	(%)	(%)	(µg/g)	(%)	(%)
1	100 m W	3700	2.79	.36	7	.50	.60
2	400 m W	1713	1.64	.40	8	.49	.35
3	800 m W	763	2.21	.40	5	.17	.17
4	50 m SSW	2193	2.24	.40	7	.32	.42
5	440 m S	1152	2.26	.39	9	.24	.37
6	1000 m S	340	2.26	.39	7	.18	.18
7	200 m N	2173	2.18	.21	5	.13	.51
9	1200 m N	298	1.12	.21	7	.30	.21

* Distance and direction from main stack.

** Distance reported represents the means for triplicate samples.

TABLE 10: Concentrations of various chemical elements in soil samples (0-10cm) collected in the vicinity of E.B. Eddy Forest Products Paper Mill at Espanola - September, 1976.

SITE		ELEMENT**					
		Na	Ca	Mg	F	Cl	S
NUMBER	LOCATION*	(µg/g)	(%)	(%)	(µg/g)	(%)	(%)
1	100 m W	175	.28	.31	183	.03	.03
2	400 m W	340	.21	.27	154	.03	.10
3	800 m W	471	2.68	.32	202	.03	.18
4	50 m SSW	277	.17	.15	163	.03	.04
5	440 m S	345	.32	.54	308	.03	.04
6	1000 m S	225	.30	.31	221	.03	.04
7	200 m N	338	.30	.54	260	.03	.05
8	640 m N	197	.08	.18	163	.03	.05
9	1200 m N	158	.12	.21	173	.03	.06

* Distance and direction from main stack

** Values reported represent means for triplicate samples except F and Cl (single samples)

TABLE 11: Condition and depth of snow at sampling sites in the vicinity of the E.B. Eddy Forest Products Paper Mill at Espanola, January 30, 1976.

SITE NUMBER	LOCATION*	TOTAL DEPTH (cm)	NO. OF CRUST LAYERS	BANDING IN PROFILE	MELT-WATER PRECIPITATE
4	550 m S	45	1	none	------
5	1000 m S	44	2	none	------
6	1750 m S	40	2	none	------
7	660 m W	53	2	none	------
8	1000 m W	44	2	none	------
9	1500 m W	33	1	none	------
10	2000 m W	52	1	none	------
11	440 m N	39	2	none	------
12	825 m W	49	1	none	------
13	1250 m N	54	1	none	------
14	1000 m NE	53	1	none	------
17	2500 m NE	54	2	none	------

* Distance and direction from main stack

TABLE 12: Condition and depth of snow at sampling sites in the vicinity of the E.B. Eddy Forest Products Paper Mill at Espanola - January 11, 1977.

SITE NUMBER	LOCATION*	TOTAL DEPTH (cm)	NO. OF CRUST LAYERS	ORANGE-BROWN BANDING IN PROFILE	MELT-WATER PRECIPITATE
1	110 m W	50	0	6, light	light
2	220 m NW	62	0	7, light-moderate	heavy
3	440 m SE	50	0	3, faint	---
4	550 m S	43	0	1, very faint	---
5	1000 m S	47	0	none	---
6	1750 m S	68	0	none	---
7	660 m W	43	0	1, moderate	---
8	1000 m W	34	0	1, faint	---
9	1500 m W	51	0	1, very faint	---
10	2000 m W	36	0	none	---
11	440 m N	48	0	1, moderate	trace-light
12	825 m N	54	0	none	---
13	1250 m N	41	0	none	---
14	1000 m NE	47	0	none	---
15	10 km NE	46	0	none	---
16	14 km NE	55	0	none	---

* Distance and direction from main stack

TABLE 13: Concentrations of various chemical elements (µg/ml) in snow samples collected in the vicinity of the E.B. Eddy Forest Products Paper Mill at Espanola in 1976 and 1977.

SITE	LOCATION*	ELEMENT***									
		SO_4		Na		Cl		Ca		Mg	
		1976	1977	1976	1977	1976	1977	1976	1977	1976	1977
1	110 m W	--	45.2	--	26.5	--	3.5	--	2.0	--	.13
2	220 m NW	--	120.0	--	79.5	--	9.5	--	9.1	--	.46
3	440 m SE	--	32.8	--	16.0	--	1.2	--	1.4	--	.09
4	550 m S	1.0	24.9	.8	20.0	1.4	1.5	.2	1.2	.02	.08
5	1000 m S	1.1	8.2	2.8	13.0	4.0	1.5	.3	.6	.04	.04
6	1750 m S	1.0	3.4	.4	5.8	.8	1.3	.2	.5	.02	.05
7	660 m W	.8	63.0	.3	41.0	.5	2.6	.2	1.8	.03	.12
8	1000 m W	1.0	44.5	.3	24.0	.4	2.6	.3	1.1	.04	.08
9	1500 m W	1.0	7.4	.2	12.0	.3	1.4	.2	.9	.02	.05
10	2000 m W	.7	3.0	.2	4.6	.3	.8	.2	.7	.02	.05
11	440 m N	1.3	35.8	.3	18.5	.5	1.8	.2	.8	.03	.05
12	825 m N	1.2	5.3	.4	9.1	.7	.9	.2	.5	.04	.05
13	1250 m N	1.1	1.6	3.5	4.2	5.3	4.1	.4	.6	.08	.07
14	1000 m NE	.8	7.0	.2	12.1	.4	1.5	.2	.5	.04	.06
15**	10 km NE	--	1.4	--	3.8	--	3.8	--	.7	--	.08
16**	14 km NE	--	.3	--	.3	--	.5	--	.6	--	.08
17	2500 m NE	.8	---	.2	--	.4	---	.6	--	.02	--

* Distance and direction from main stack

** Control locations

*** Reported values represent mean values of duplicate samples

TABLE 14: Concentrations of various chemical elements and other parameters for snow samples collected in the vicinity of the E.B. Eddy Forest Products Paper Mill at Espanola in 1976 and 1977.

SITE NUMBER	LOCATION*	K µg/ml		Alk.		pH		Cond.	Fe µg/ml	Tannins & Lignins µg/ml
		1976	1977	1976	1977	1976	1977	1977	1977	1977
1	110 m W	--	1.85	--	10	--	6.6	170	.2	3.3
2	220 m NW	--	5.40	--	46	--	8.2	475	.5	10.0
3	440 m SE	--	1.08	--	6	--	6.3	103	.3	2.0
4	550 m S	.03	1.38	4	7	4.4	6.6	124	.1	.5
5	1000 m S	.04	.86	2	4	4.4	6.5	82	.3	.3
6	1750 m S	.02	.38	1	1	4.4	6.1	44	.1	.0
7	660 m W	.03	2.58	1	11	4.4	6.3	238	.4	1.5
8	1000 m W	.05	1.45	1	7	4.4	6.2	140	.2	.5
9	1500 m W	.04	.75	1	5	4.4	6.0	76	.1	.0
10	2000 m W	.04	.75	1	1	4.4	6.0	36	.2	.0
11	440 m N	.04	1.25	1	7	4.4	6.3	117	.7	1.0
12	825 m N	.06	.60	1	4	4.4	6.4	58	.1	.0
13	1250 m N	.08	.16	1	1	4.4	6.3	37	.2	.0
14	1000 m NE	.05	.80	2	6	4.4	--	73	.2	.3
15**	10 km NE	--	.16	--	1	--	6.2	37	.2	.0
16**	14 km NE	--	.10	--	1	--	--	20	.2	.0
17	2500 m NE	.04	--	1	--	4.4	--	--	--	--

* Distance and direction from main stack

** Control locations

*** Reported values represent mean values of duplicate samples


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